An Analysis and Review of Measures and Relationships in Space Transportation Affordability

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An Analysis and Review of Measures and Relationships in Space Transportation Affordability

- Affordability, Prices and Costs
  - Poor data, $/kg, $ per flight, and many, many caveats
- Productivity, Flight Rate and Yearly Capability
  - Flights, tonnage
- Competitiveness
  - Current vs. Growth
- Direct vs. Indirect Costs
  - Where vs. Why, Comprising vs. Causing
- Closing

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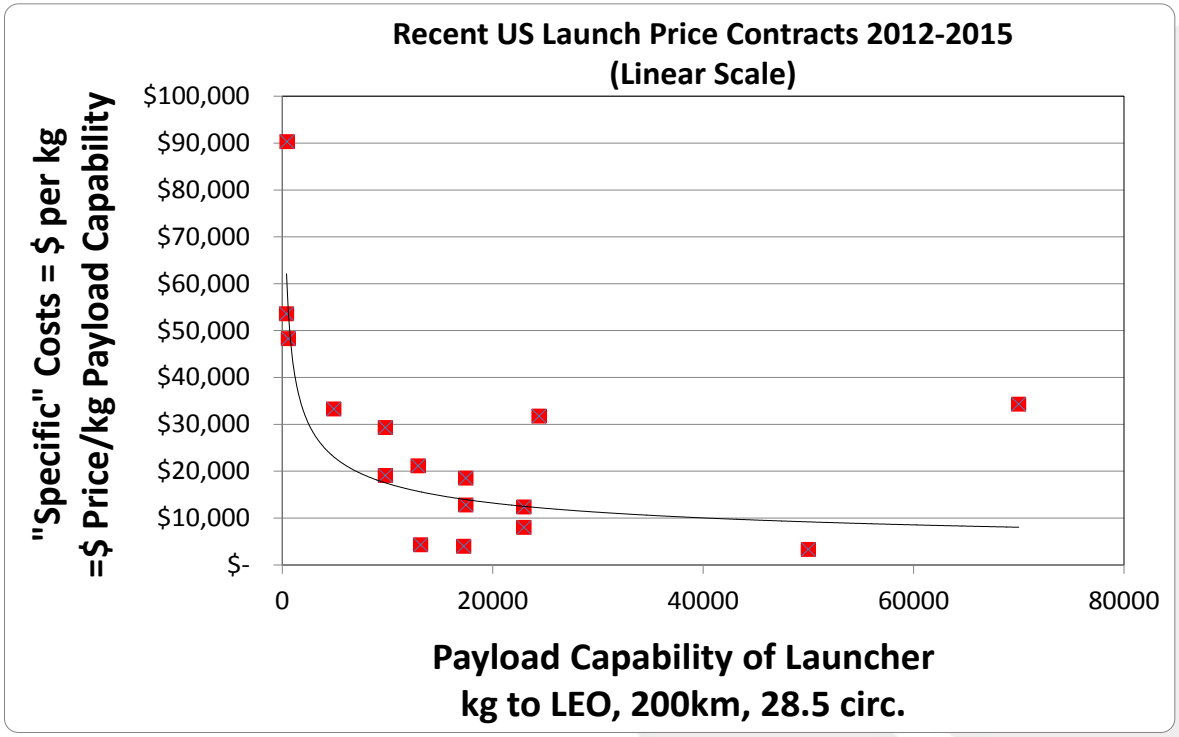

Figure 1: US Launchers and recent launch price contracts (2012-2015), using a linear scale and applying a power curve fit.

- A typical view of affordability
- Recent data used here
- Poor state of data, many contracts not public
- Causality (X to Y) not implied nor clear

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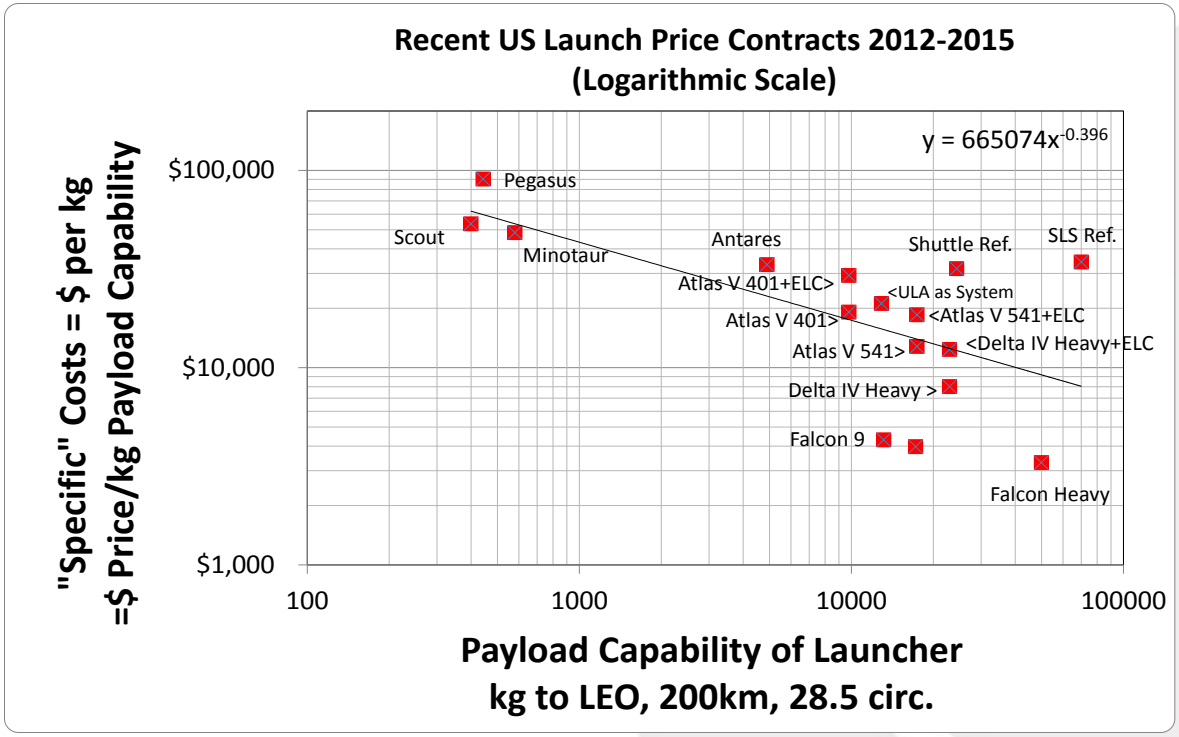

Figure 2: US Launchers and recent launch price contracts (2012-2015), using a logarithmic scale and applying a power curve fit.

- **Shuttle only as reference (more ahead on apples/oranges)**
- **Poor state of data**
- **Similar to what an airline would have as CASM-cost per available seat mile**
- **Relative indicator of competitiveness**

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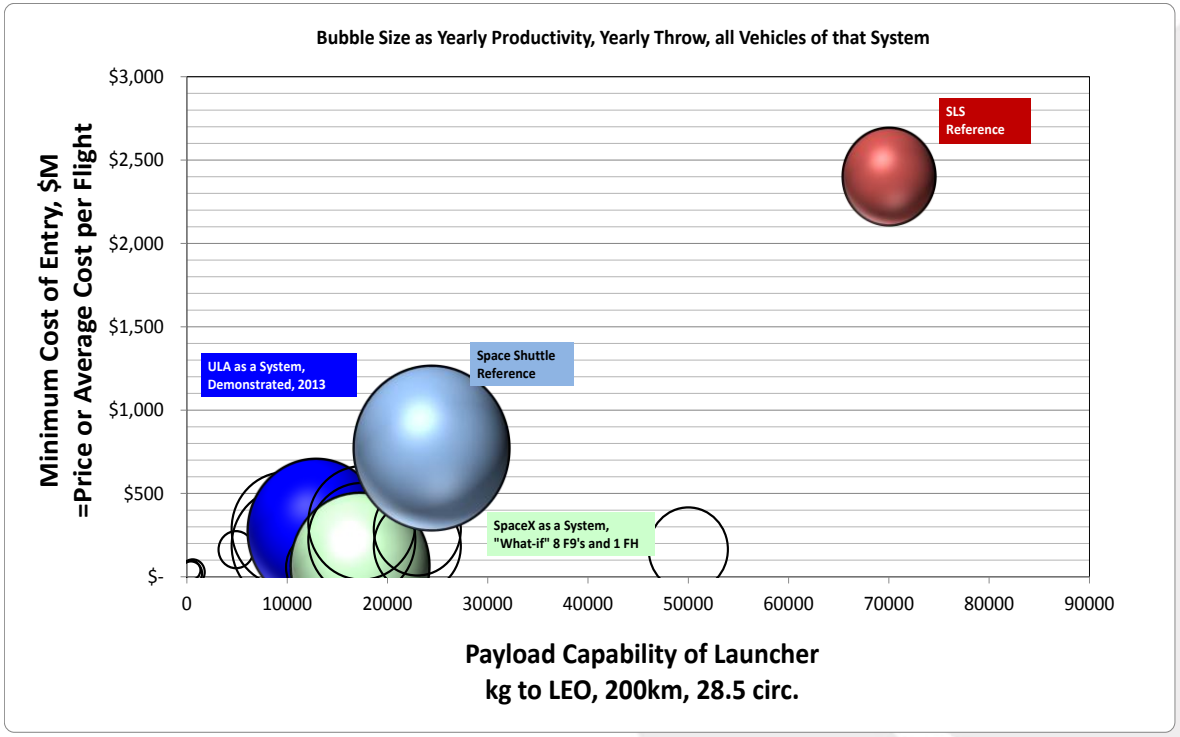

Figure 3: Using a bubble chart to show three variables; average payload capability of a system of launchers, the average cost of entry (or price to a customer), and the total tonnage capability deployed over a recent calendar year, as bubble size.

- Treat common capabilities as a system (all ULA, all SpaceX, etc.)
- Tonnage "capability" (not "actual"; more on this ahead)
- Want the bubble sizes to grow, and want more bubbles!
- US launchers only

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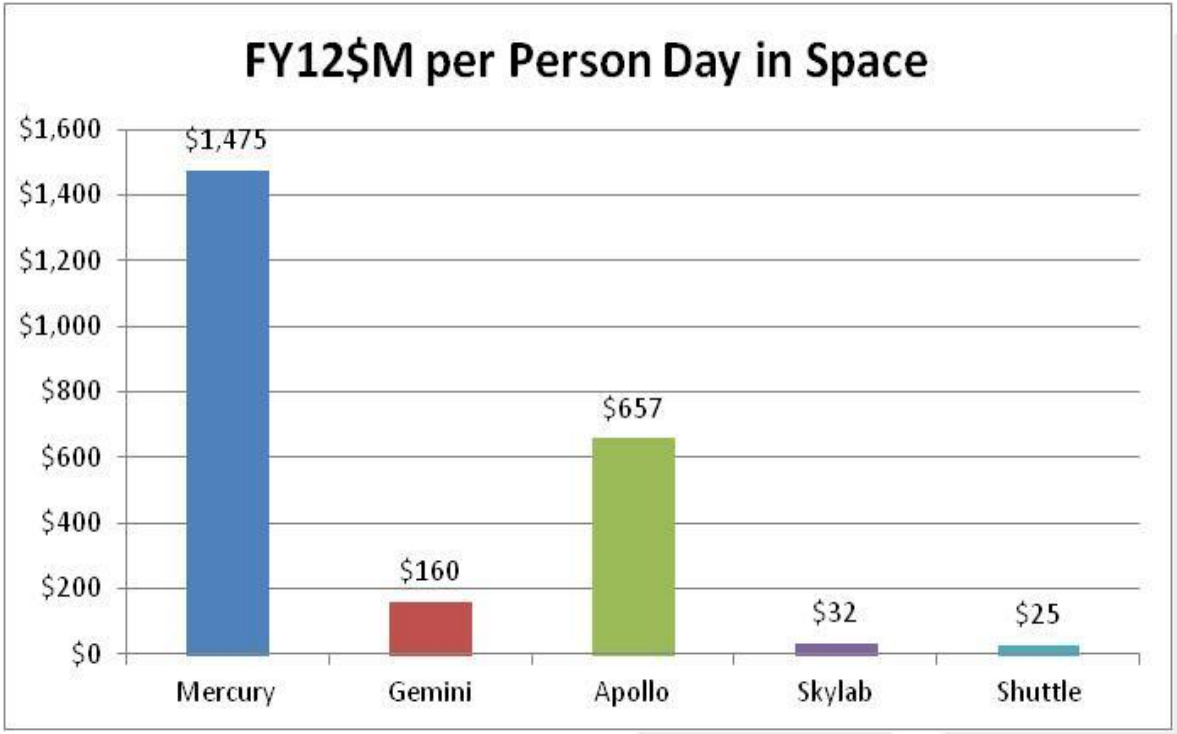

Figure 4: Courtesy Andy Prince, "Human Spaceflight Value Study, Was the Shuttle a Good Deal?" NASA Cost Symposium, 2012.

- **On Shuttle: Measures of use to stakeholders go beyond cargo, kg, etc.**
- **Shuttle very "affordable" –by this measure and requirement, people to space**
- **Many affordability measures beyond $/kg or price per flight**
  - **Productivity, of some "value"**

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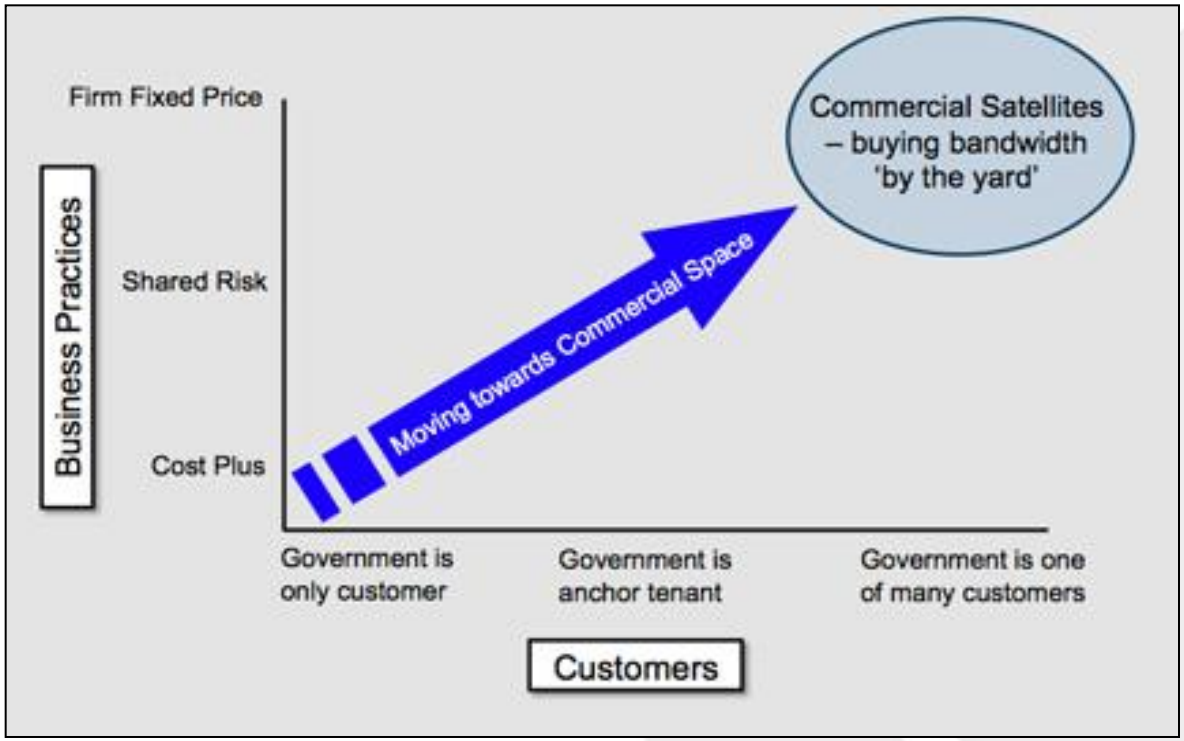

Figure 5: What is "commercial" space to NASA?

- **Emerging / commercial space of great interest**
- **Visually, a spectrum of being more or less commercial**
- **Can compare two or more players as being more or less commercial**
- **Commercial is not about just being private sector; it's much more**

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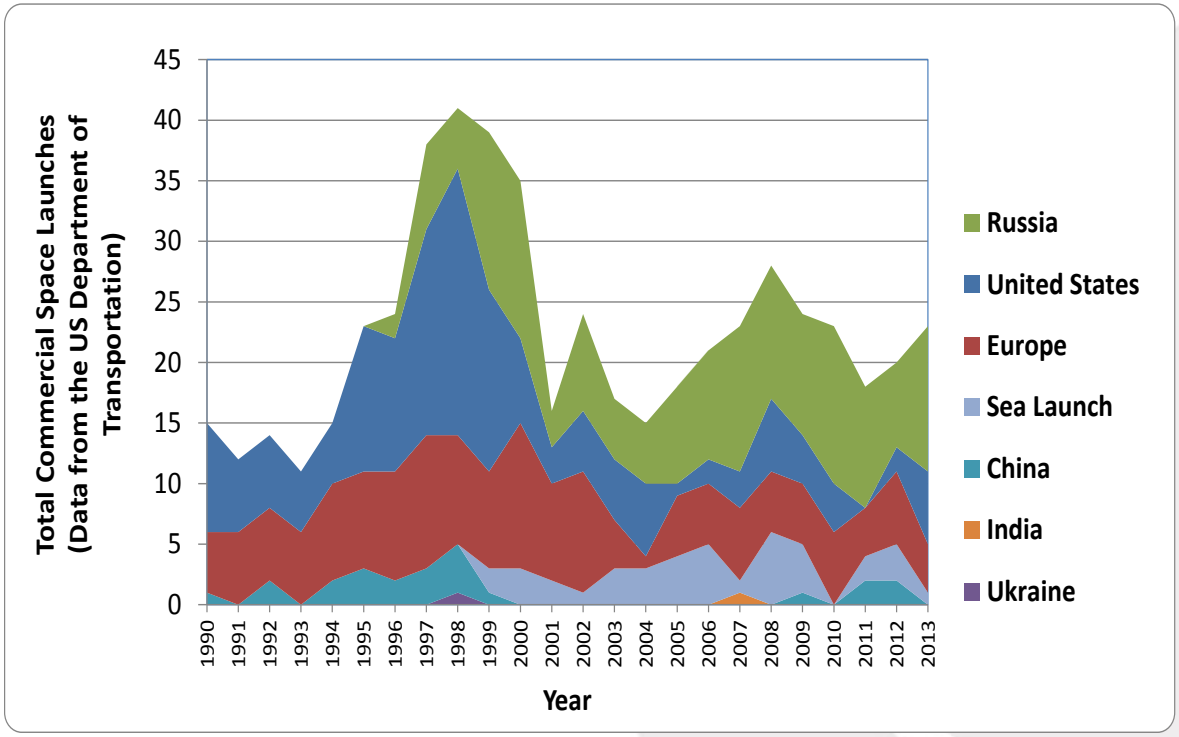

Figure 6: Graph created from raw data at the Department of Transportation for launches through 2012, plus 2013 data from the Federal Aviation Administration, "Commercial Space Transportation 2013 Year in Review,"

- **Globally: Appear to be stagnant at about 20 commercial launches/year**
- **Definition is "competed" or "FAA licensed"**
- **2013 - US appearing to see an uptick ? (but not the total market)**
- **What might cause market size to grow? Affordability + Productivity?**

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Table 1: Basic ingredients for a space exploration element (launch, spacecraft, habitat, etc.) being more commercial. The more these ingredients are captured, the more commercial the element is.

Ingredient	Rationale
Product development and use, amortizing costs	The business case depends on having non-government customers. The product for the government is developed with non-government customers in mind. The product or service is also provided to non-government customers.
Contracts	The government uses firm fixed price type of contracts.
Efficiency	Provider applies mostly commercial best practices. These practices or "how" are outputs. Capability, performance, safety, and cost goals are inputs.
Incentives	Multiple suppliers (industry) and multiple buyers (government and non-government) rationalize incentives, leading to success even when many requirements (performance, safety, cost) appear at odds. No monopoly (single provider) or monopsony (single buyer).

The formal, actual definition of what is "commercial" is expressed in the current space policy: *"The term "commercial," for the purposes of this policy, refers to space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment, and have the legal capacity to offer these goods or services to existing or potential nongovernmental customers."*

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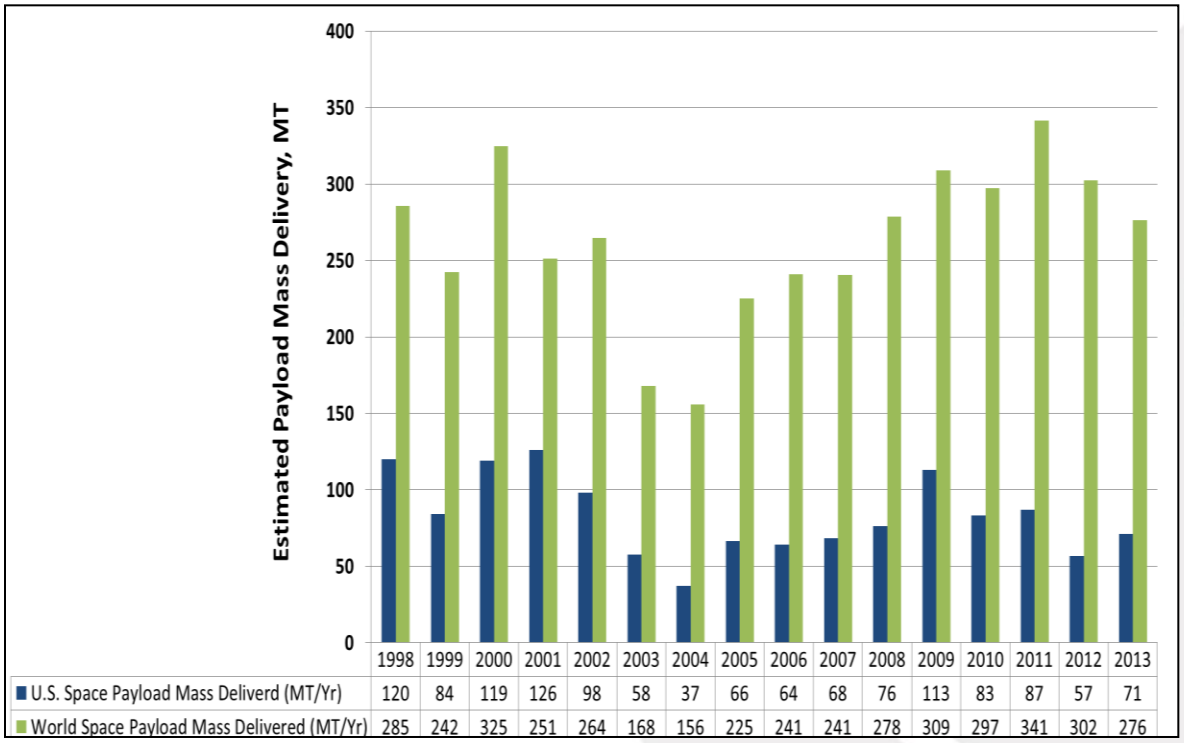

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
U.S. Space Payload Mass Deliverd (MT/Yr)	120	84	119	126	98	58	37	66	64	68	76	113	83	87	57	71
World Space Payload Mass Delivered (MT/Yr)	285	242	325	251	264	168	156	225	241	241	278	309	297	341	302	276

Figure 7: A view combining the launch record with estimated actual payload masses.

"Actual" tonnage being less than "capability" of launcher would mean far more $/kg and price per flight, in practice.

The data here has been compiled from two main sources:

(1) FAA Commercial Space Transportation, Year in Review reports

(2) Payload launch masses estimated from SpaceLaunchReport.com.

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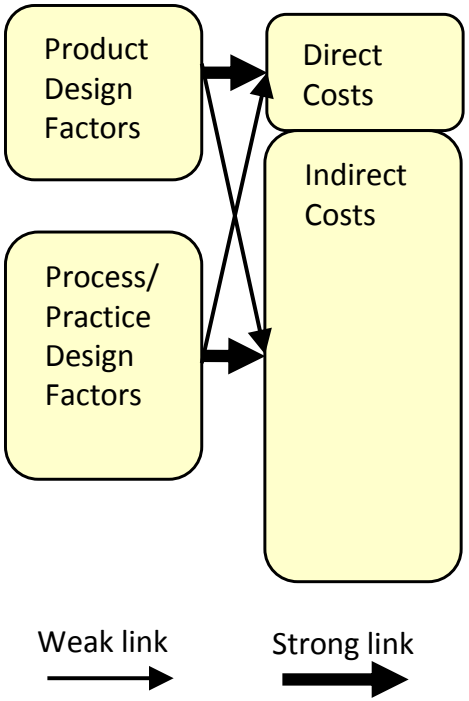

Methodology / model used in current models and analysis

Figure 8: Technical product design factors ("what"; such as a number of parts, or different fluids, or the type of fluid, and reliability, etc.) distinguished from non-technical process factors ("how"; such as development practices, the flow of information, manufacturing steps, etc.)

Needs:

- Acceptance: Project/program cost data as a necessity, not a cost itself, not a luxury
- Insights, traceability
- Understanding and separating what comprises costs from what causes costs (not the same thing)
- Getting into the less tangible, less "technology" alluring indirect
- Technology that focuses on direct processes/responsiveness, productivity, in all phases from manufacturing to ops and launch; not just in flight

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- What is needed is and ability to discriminate:
  - cost-per-pound of launch vehicle payload capability
  - cost-per-pound of payload delivered
- Specifically, need cost and productivity information:
  - Annual Production and Supply Chain Costs as a function of Unit Production Rate
  - Annual Operations Costs as a function of delivery (flight) rate

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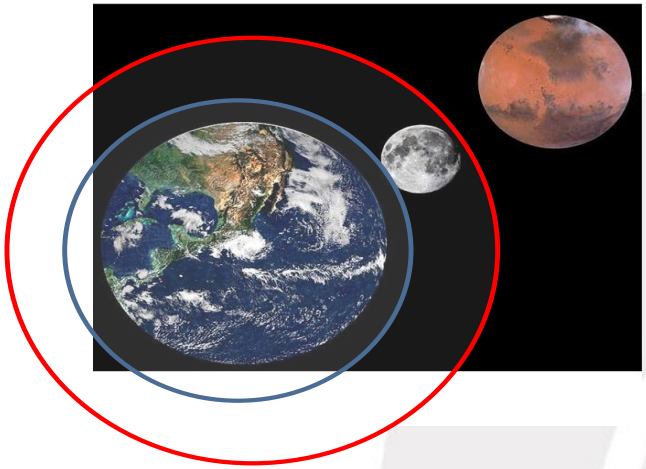

? Time
? Flight Rate & Productivity

Gen 1
X% of Spaceflight Budget = Transportation

Same Affordability

Gen 2
X% of Spaceflight Budget = Transportation

Figure 9: If some fixed resource is dedicated to launch, and a business or government enterprise also wants to go further, for longer, then launcher/transportation affordability must significantly improve.

- **Always the same few variables: resources, time, flight rate**
- **Stretching time/schedule, or dropping flight rate only gets so much**
- **Assuming budgets as in last 40 years, affordability, productivity and competitiveness must improve to allow space development and exploration**

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